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RAINS CULTIVATION

BY

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From the earliest days of man's history agriculture has been pursued and in the course of many centuries much practical knowledge has been accumulated, but it has been only in comparatively recent times that it has become recognised that the natural sciences can assist the Agriculturist towards a better appreciation of the problems confronting him. Agriculture in the past has been a method of the rule of thumb and improvements have been effected only by a very slow process. Science has now, however, been commandeered to assist in its development and perhaps one of its primary duties at the present time is not to alter agricultural methods so much as to explain the reason for performing the common operations. The experience of the ages has taught men the necessity of cultivating the soil if crops are to be grown and as a consequence of this certain principles have become recognised, but it is not always fully appreciated how best to adapt such general principles to the particular conditions of soil, climate, etc. It is with the object of helping towards the better understanding of the effect of some of the operations of cultivation that this article is written so that men shall be in a better position to adapt the general principle to their own particular needs. It is not intended to enter into a discussion of the whole question of cultivation but as the title of the article suggests into only one aspect of it, namely, cultivation in the rains.

In respect to cultivation in the rains our opinion in general terms may be expressed as follows :—Hoeing in the rains generally does more harm than good. When it is considered that a large proportion of the increase of tea crop in the past 15 years or so has been due to cultivation, the above expressed opinion requires

explanation and it becomes necessary to examine in more detail the effects of cultivation as carried out in the operation of hoeing during the rains. What are the benefits that are expected to arise from hoeing ? These can be briefly summarised under three headings :—

(1) The keeping down of jungle :

(2) Increased availability of food to the bush :

(3) A better physical condition or state of tilth in the soil.

The increased availability of food to the bush is of course largely dependent upon the physical condition of the soil ; and improved tilth includes amongst other things better aeration of the soil.

Jungle undoubtedly does harm to the tea among which it grows. It becomes a competitor for food and water and also any plant growing in the neighbourhood of another plant exerts a poisonous effect upon it. Undoubtedly the main benefit that has been derived from hoeing in the rains has been from the removal of jungle.

The effect of hoeing on the physical state of the soil has not always been good. When the soil is too wet, not only does it produce no improvement, but actually spoils the existing tilth. Very fortunately, hoeing does not exercise the same sheering effect as does ploughing, and ordinary light hoeing in the rains generally amounts to little more than cutting through the roots of the jungle at a very shallow depth below the surface. Further the very presence of the jungle tends to minimise the puddling effect which ruins tilth.

Loss of tilth from rains hoeing has therefore been slow, particularly as the drying of the soil during each cold weather acts in the opposite direction and restores at least a great part of the lost tilth.

Probably even more serious than the effect of the hoeing itself has been the effect of heavy rain beating on an unprotected surface of clean loose soil.

Not only does this beating directly puddle the soil and leave a most unpleasant 'skin' on the surface (insufficiently pervious to water and air), but the finer soil particles are washed down, leaving the surface much more sandy indeed, but tending to 'pan' the soil at a little below the cultivation depth, thereby greatly interfering with the efficiency of the drainage.

After many years the bad effect of hoeing wet soil, and of leaving clean soil exposed to the rain, has become apparent on many soils.

In a soil in good tilth the very small sticky colloidal clay particles join together to form a smaller number of large particles or aggregates, and thus the soil loses much of its clayey nature ; it becomes less sticky and the increased size of the various interspaces between the aggregates allows a freer movement of air and water. The puddling effect of hoeing in the rains causes these aggregates to break down, the soil becomes more sticky, less pervious to water, and more inefficiently aerated. These physical effects cause changes in chemical and biological reactions in the soil. The soil acidity increases, nitrification becomes slower, and plant foods generally become less available and in extreme cases actually are lost altogether.

Since puddling affects the clay particles of a soil, the effect of rains hoeing is seen at its worst on soils of a high clay content. All fertile soils, however, contain some clay and therefore the effect is produced on all soils though to different degrees. Sandy soils containing little clay may be so little affected, that the effect is completely reversed at the next drying so that no permanent harm results ; and there are a few extremely sandy tea soils so deficient in the colloid particles which 'bind' a soil, that puddling of the very small quantity of clay present, may actually be beneficial.

With the exception of these sands however, it is clear that hoeing during the rains would be better avoided.

During dry periods when breaks in the rains occur, hoeing often becomes possible and as much should be done then as is practicable. Good drainage is at such times of very great

assistance since it will permit of hoeing to be commenced sooner and the time increased during which hoeing will do good and not harm.

To the cessation of hoeing during the rains there are two great objections.

The first is that hoeing is hard exercise, and a labour force soon gets out of training if hoeing is dropped, so that when hoeing is resumed the men get sore hands, and their unused muscles cannot do the work which they performed with ease when in condition. In some cases the men actually become unwell, from the loss of the exercise to which they had become accustomed.

Objections have also been made that a garden cannot afford to pay labour to sit in the lines and do nothing. Since it is clearly better to pay men to do nothing than to pay them to do harm, this objection has little force.

However it is necessary to provide alternative work. On many gardens all the labour available can be used for plucking ; while methods of keeping down jungle other than hoeing (which will be dealt with later) also, of course, use labour, but neither of these will keep the men in condition and it is advisable to provide as much work as possible, which involves the swinging of a hoe.

When the soil is wet the digging of drains, and the deepening and cleaning of old ones is very much easier than in the cold weather. The area of which the tilth is thus spoiled is in any case small, while if the excavated soil is left heaped up until the cold weather, it will be subjected to that alternate wetting and drying which rapidly produces a state of good tilth.

Trenching is also easy work during the rains and it would be of great advantage to get in crops like Arhar before they get too woody. In this case, however, some care would be necessary. The filling in of the trenches should be left till a time when the soil is not too wet, otherwise the puddling effect may be serious. In the cold weather trenches should be filled in as soon as possible to avoid undue drying out of the soil. In the rains, trenches could be left open with good effect. Trenching, however, could be

done in the rains only on a small scale. From good yielding tea, the cutting of the root ends would decrease the flush for the remainder of the season. In young tea, however, and in cases where the state of the tea warrants some sacrifice of present crop for the sake of future yield, trenching in the rains is strongly recommended as an alternative to hoeing, provided that the filling in of the trenches be done when the soil is not so wet as to puddle on working.

Assuming that a manager can so arrange his work that the men can be fully and satisfactorily employed during the rains without hoeing work, there still remains the serious problem of keeping down the jungle.

Without any doubt the presence of much jungle produces serious loss of crop, and during the rains, the jungle is growing very rapidly indeed.

If we examine the factors which make up the harmful effect of jungle on tea,—competition for water, competition for food, and toxic effect on neighbouring bushes—it is at once clear that the most serious factor of competition for water is not active at all at the times when it is recommended that hoeing shall not be done. The soil has then too much water, and it is therefore obvious that there is more than enough water present for tea and jungle both.

A full explanation of the last factor (of toxicity) is not yet agreed upon. It is very probably due to the presence of too great a concentration of carbon dioxide, and to a corresponding deficiency of oxygen in the soil. Rain water falling on, and percolating through a well drained soil carries with it dissolved oxygen from the air and keeps the soil thoroughly well aerated, while excess carbon dioxide (or other soluble toxin if there be any) is at the same time washed out. The toxic action of jungle then is also at its minimum during the rains.

The only bad effect of jungle which is active in the rains is the competition for food, and this of course may be serious. The loss of food by washing out however is also very serious and such loss is permanent. The presence of some jungle will minimise this loss by washing and such food as is taken up by the jungle is always returned to the soil when the jungle decomposes after

being buried. The buried jungle also supplies to the soil organic matter which has very largely been obtained from the air.

The jungle thus acts as a "catch crop." The term "catch crop" is used in general agriculture to mean a crop specially planted when in the ordinary rotation the soil would otherwise be fallow. The special function of the catch crop is to take up the soluble plant foods (nitrates forming the most important part), which would otherwise be washed out and lost.

When it is remembered also that the presence of jungle not only prevents the puddling of the surface of the soil by rain, but actually by its root action improves the tilth of the soil, it will be clear that the presence of some jungle may not be altogether a bad thing on soils where the tea does not cover the ground.

If the tea completely covers the ground it of course provides all of these advantages for itself. It will not allow the beating of unprotected soil by rain, its roots will very thoroughly explore all the available soil and so reduce the loss of soluble food, and by its prunings it will maintain the organic matter content of the soil. In addition it will keep down jungle for itself ; for jungle will not grow in thick shade. A good food supply will of course be necessary either from a naturally very rich soil, or from manuring.

There are in the Surma Valley rich clay flats giving over 20 mds. of tea per acre which are either never cultivated or get no more than two or three scrapings in a year. The soil is absolutely free of jungle and is in beautiful tilth. They would gain in improved aeration and gain greater efficiency from buried prunings, if a cold-weather hoe could be given, but in a place as described a hoe cannot be swung, and where any cultivation at all is given, it amounts to little more than scratching the soil with a hoe pushed under the branches. Yet with no cultivation (or practically none) the soils are in beautiful tilth. Many regularly well-hoed soils are very bad in comparison.

These rich clay flats are here interesting, firstly because they demonstrate that tilth may be maintained without hoeing, and secondly because they suggest a means of minimising the necessity of hoeing to keep down jungle.

Where the tea itself does not cover the ground (as is the usual case, even though outside branches are frequently lightly touching) the use of shade will assist very effectively to keep down jungle, and will also provide the advantages of a catch crop to greater or less extent.

The low growing leguminous plants usually used as green manures perform the functions of a catch crop perfectly, particularly having regard to the time of sowing—March to May. It is at this time that nitrate formation is likely to have reached a maximum, and loss of nitrates by washing out is therefore prevented over a critical period. The green crop also kills out jungle by its very denseness and ability to grow rapidly. The growth of a crop like cowpeas is very strongly advised where there is much jungle of a particularly undesirable nature, like thatch grass.

More effective shade can be provided by a taller crop like Dhaincha or over a greater part of the season by semi-permanent crops like Arhar or Boga medeloa. When these latter are planted as hedges between every second or third row of tea a greatly reduced jungle growth is obtained.

Shade trees also contribute to the same effect. One does not see serious trouble from thatch grass or other deep rooted and tall grasses under shade trees, but plants like Ageratum (Ilami, cold weather weed) or shallow-rooted, low-growing grasses which do little harm become established.

The tea bushes, like the jungle, might be expected to suffer from the shade effect. Tea however is one of the plants actually benefited by light shade, although an amount of shade which keeps down jungle altogether would certainly do harm to the tea.

It is clear then that green crops and shade trees may be used to reduce the necessity for cultivation in the rains, but of course it is not expected that green manures and shade trees can be grown all over a garden at once.

It has already been pointed out that a light covering of jungle, during the rains, is preferable to absolutely bare soil ; but deep-rooted and tall jungle must never be allowed to become established

nor should even better types of jungle be allowed to become excessive.

On the greater part of the area of most gardens direct methods will have to be adopted to keep down jungle. It is the main object of this article to insist that hoeing should be pushed on as rapidly as possible whenever the soil is not too wet, but that other methods should be adopted whenever it is clear that hoeing would puddle the soil. At the same time it is not desired to establish an absolute rule that no hoeing must be done in the rains. Where bad types of jungle like thatch are prevalent the damage done by it may be more than would be done by a single hoe in the rains. Still, even then the hoeing need not be done when it is actually raining.

Bearing in mind the principles which have to be considered the Manager's discretion will have to be used.

Alternatives which are preferred to hoeing are hand forking and sickling which should be used in combination.

The forking will aim at establishing a circle, of about 3 feet diameter around the bush, which is absolutely clean weeded. Within this circle jungle will hardly get a start since it is well covered by the bush, and this clean surface will provide free exchange of gases between soil atmosphere and the air above, thus ensuring aeration of the soil around the bush.

This forking will naturally be much better applied when the soil is near its optimum water content, but when the soil is wet it can be made rather a pulling out of weeds by hand assisted by the fork, than an actual working of the soil.

The jungle between the lines may be left to grow to some height without any great loss to the tea (at times when there is water enough for both), and whenever it is considered excessive it may be sickled by hand. A proper application of forking and sickling should at least reduce the necessity for hoeing to a minimum.

It may be pointed out that all these methods of doing without hoeing during the rains will be particularly valuable on slopes

and teelas where cultivation not only ruins tilth but leads to greatly increased loss of soil by wash. In these situations the very best cover crop is the tea bush itself. Teelas and slopes should therefore be close-planted and kept continually infilled.

Summary.

1. Hoeing a wet soil ruins the tilth.
2. In the rains the soil is generally too wet, and therefore hoeing in the rains should be avoided.
3. Unless cultivated, soils will grow jungle, which in excess is harmful.
4. In dry intervals hoeing improves tilth, and hoeing should then be carried on as rapidly as possible.
5. This alone will not generally keep down jungle sufficiently ; but rather than spoil tilth by hoeing wet soil, hand-forking and sickling should be used.
6. Green manure crops greatly assist to reduce jungle.
7. Shade greatly reduces jungle growth. It may be provided by tall green manure crops like Arhar, by shade trees, or the tea bush itself. If grown to cover the ground thickly and completely no jungle at all will grow under tea, and in that case hoeing may be dispensed with all together, except when the soil is at its optimum water content.
8. The hoeing men who by dropping hoeing may be left unemployed may be used for draining, trenching, hand-forking, and sickling.

METEOROLOGICAL OBSERVATIONS IN ASSAM.

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Introduction.

Generally speaking there are two sets of factors affecting the tea crop in North-East India—weather and soil condition. The type of bush, the method of pruning and plucking are secondary factors. It is possible to influence profoundly the soil condition not only by drainage and cultivation by also by the use of fertilizers and manures. The weather is beyond our influence and, so far, meteorology in Assam has been so little studied that we are even unable to predict the weather with any degree of certainty. True there is not the necessity in Assam that is felt in colder climates where the prediction of a frost is of great service to cultivators. It may also be argued that the tea bush is a perennial and that a close study of the weather cannot lead to any direct improvement of crop outturn This view is incorrect.

The importance of meteorological observations and the necessity for opening stations at critical intervals over a country has been recognised by Azzi (1) and his work has been taken up and modified by Carton (4) in connection with agriculture in Indo-China.

Azzi, by studying the relationship between the plant and the climate and the plant and the soil hopes to develop the science of agricultural geography. This science will consider the distribution of plants not as static but as dynamic systems in that they are functions of the medium in which they, the plants, live. The science thus becomes essentially biological and more especially a branch of the science of ecology.

Before studying the tea crop with regard to climatic conditions in any special year it is instructive to follow the growth periods of the tea bush. With annual crops there is a *critical period* following sowing during which certain conditions must hold if the crop is to be successful. This period interests the tea planter so far as nurseries and green crops are concerned. With regard to the fully grown bush, the months of March, April and May following on the cold weather drought are critical, and during

this period unless rain falls the bushes are seriously affected. When a bush is collar-pruned this period becomes still more critical and for this reason heavy pruning should be carried out as early as possible so as to minimise the effect of a drought.

In February the bushes begin to come away in normal years and during the next two months they are "tipped." A shoot which is plucked in March or April gives rise, on a straight flush, to six shoots corresponding to the monthly flushes in May, June, July, August, September and October. Ten years ago only five flushes could be recognised and the addition of an extra flush is due, no doubt, to improved methods and treatment. A close study of the meteorological conditions enables us to accurately foretell these flushing periods.

From the above it is obvious that the weight of the crop given by the "tipping" influences the total crop although the number or shoots may be made up on the May or later flushes. When the bushes are growing vigorously shoots are produced from more than one axil and the total number of shoots from one original tip may reach ten or twelve during the season. These extra shoots mature at periods different from the flush and may partly mask the latter. On this account a weekly crop can be obtained.

The Monsoon in Assam during 1921.

In Assam, the monsoon, as denoted by rainfall, is not so well defined as in Bengal. The early rains often run on till the true monsoon breaks. This was particularly the case in 1921.

Below is shown the rainfall recorded at Tocklai during the past 4 years together with the calculated degree of wetness for each month. It is obvious that the total rainfall over a certain period does not signify so much as the distribution of rain over the same period. Half an inch of rain in the middle of a wet spell has as much effect on a soil as two or three inches during the same spell. The degree of wetness is calculated as follows :—

$$\frac{\text{Rainfall} \times \text{No. of wet days.}}{\text{No. of days in month.}}$$

The significance of the degree of wetness may here be considered. Taken over a long enough period this factor would show little variation. So far as the tea crop is concerned the interval between successive flushes would be a more suitable period for considering the degree of wetness. Thus in 1919 a dry period commenced towards the end of July and continued throughout August so that the flush was quite obliterated. Yet the degree of wetness for July does not appear to be deficient. By taking the degree of wetness over a shorter period, as yet unfixed owing to insufficient observations, a much nearer correlation between rainfall and crop could be obtained.

Another factor to be considered in connection with the degree of wetness is that of temperature. An inch of rain early in the season or in October has as much effect on the soil as a much greater fall in the hotter months. In October 1921 when the degree of wetness was 2·66, the soil was as moist as during the previous month when this factor was 9·49, but the temperature much higher.

The degree of wetness as calculated below may only be taken as a first approximation to a measure of rainfall effect.

The distribution in 1921 compared with other years was particularly favourable until November during which month no rain fell. On account of this early close the crop suffered severely.

Table showing Monthly Rainfall and Degree of Wetness at Tocklai.

Months.	Rainfall in inches.				Degree of wetness.			
	1918.	1919.	1920.	1921.	1918.	1919.	1920.	1921.
January	0·12	0·28	0·63	1·63	0·004	0·02	0·04	0·42
February	1·26	0·97	2·73	0·86	0·18	0·17	0·87	0·21
March	6·37	0·75	6·15	4·21	3·29	0·07	2·97	1·22
April	5·91	7·41	9·08	14·03	2·16	1·91	3·60	10·29
May	15·42	6·57	6·73	9·28	6·96	2·54	2·38	5·08
June	14·92	22·09	9·89	7·71	8·61	12·51	6·59	6·42
July	18·20	16·37	14·18	14·52	11·77	10·56	8·46	9·84
August	19·48	10·71	9·22	9·71	11·31	4·42	5·94	6·57
September	12·44	9·59	6·17	14·23	6·22	5·75	3·08	9·49
October	2·42	9·40	2·47	5·15	0·31	3·33	0·72	2·66
November	0·40	0·40	0·40	nil	0·13	0·56	0·26	0
December	nil	0·11	0·13	1·14	0	0·01	0·01	0·11
Total	96·94	75·08	67·55	82·47				

The prevailing wind in the Assam Valley during the monsoon is South-West. During the cold season it is North to North-East. All the monsoon rain is brought originally from the South either round the Garo Hills or by way of the Jetinga Valley. The former wind usually strikes the Tezpur district and is then reflected to the South bank of the river where it impinges against the Naga Hills somewhere about Moriani. In this manner, Tocklai just escapes the rain whilst precipitation takes place along the lower ranges of the Naga Hilla a few miles away. At night, however, the wind which blows from the hills to the plains deflects the moist wind from its general direction Numaligarh-Nakachari and it is then that Tocklai receives most of its rain. The hotter the day the earlier is the evening precipitation. The total rainfall at Tocklai is about the same as that under the Naga Hills.

The wind which blows up the Jetinga Valley precipitates rain evenly up the Assam Valley. The area below Golaghat receives most of its rain from this source and very little from the other source. Thus the rainfall at Nowgong is only about 60 inches, which is about the limit below which tea will not grow luxuriantly.

During the rains heavy rainfall is naturally accompanied by a fall in temperature, but before the monsoon has broken the opposite is noticed. This is because the rain-bearing wind originates in the South, although it has often moved round the hills which surround the Valley, so that it appears to blow from the North.

Vapour Pressure and Temperature Considerations.

The atmospheric vapour is one of the chief climatic factors influencing the tea crop in North-East India. The relative humidity varies from about 80 to 95, but the vapour tension varies to a much greater extent.

The vapour tension of the atmosphere is a measure of the total atmospheric moisture. Although the monsoon as denoted by rainfall is not very well marked in Assam, it can easily be followed by the vapour tension curve. Generally speaking, monsoon conditions exist from the end of May to the end of September. During this period the pressure from the Bay of Bengal is

continuous and the Brahmaputra Valley receives a steady inflow of moist air. This is clearly shown on the curve below.

In addition to this, the whole of Assam during the rains resembles a great lake supplying an unlimited amount of moisture to the atmosphere. In spite of this the day is never long enough to bring about complete saturation of the atmosphere—about 75% saturation is usual. At night when the temperature drops to the neighbourhood of 80°F saturation and precipitation as dew occurs. A hot day greatly increases the vapour pressure, and the following night is insufficient for complete precipitation of the vapour in excess of saturation. In this manner the vapour pressure will follow mainly the daily temperature, for the night temperature, as will be seen from the curve, is fairly constant and does not vary nearly so much as the maximum temperature.

The effect of temperature and vapour pressure on the tea crop will now be considered.

The transpiration rate of a bush has a great deal to do with the rate of growth, for if transpiration is rendered difficult then the bush grows more leaves in order to carry on the process. Transpiration is a vital process and is dependent chiefly on the temperature. Sewell Wright (7) dealing with the rate of transpiration of leaves mentioned in the researches of Briggs and Shantz (3) gives the following correlation between rate of transpiration of leaves and meteorological conditions :—

$d_t = 0{\cdot}55$, $d_h = 0{\cdot}18$, $d_w = 0{\cdot}09$, $d_r = 0{\cdot}04$

and for evaparation from a shallow tank—

$d_t = 0{\cdot}30$, $d_h = 0{\cdot}19$, $d_w = 0{\cdot}16$, $d_r = 0{\cdot}16$

where d_t represents the degree of correlation between temperature and transpiration or evaporation, d_h the degree of correlation for humidity, d_w that for wind and d_r that for radiation.

It may here be mentioned that the degree of correlation between two factors is a measure of the dependence of one factor on another. Thus if $d_t = 1{\cdot}0$ this would signify that evaporation is wholly governed by temperature. It will be observed that the sum

of the correlation factors falls short of unity and this deficiency is a measure of the outstanding, unconsidered factors.

The four factors are much more nearly equal in importance in the case of evaporation than in the case of transpiration. The influence of temperature is seen to be in the latter case much greater than that of the other factors, and about three times as great as that of humidity.

During the monsoon the difference between the maximum and minimum temperatures in Assam is only about 10°F. In the cold season this difference is about 20°F, the low night temperatures accounting chiefly for the increased difference. It is undoubtedly this difference which stops the flush during the cold season. The period when humidity is usually most deficient is during October when the vapour pressure falls at a much greater rate than temperature. In seasons when this deficiency does not occur, October is often the best month for crop. Towards the end of the year a state of saturation exists every night, and in this respect monsoon conditions are realised although the temperature is much too low for the bushes to flush vigorously.

Observations made at Heeleaka (5) some years ago showed that the tea crop, with certain exceptions, closely followed the temperature.

Thus when the temperature rises abnormally, the crop goes down. This depression, however, will cease as soon as vapour pressure conditions approach equilibrium and it is not likely to occur if the temperature rises slowly day by day, for then the atmosphere never becomes excessively dry. A period of low temperature resulting from copious rainfall also depresses the crop. In this case there is no deficiency in humidity, and temperature is the sole cause, not considering soil condition, of crop depression.

Studying the rate of growth of plants Briggs, Kidd and West (2) have come to the conclusion that temperature is the chief factor influencing crop.

Livingstone and Livingstone (6) correlate the rate of growth of plants with temperature and show it to follow Van't Hoff's law

for general chemical reactions. Thus for every 18°F rise in temperature the rate of growth will be doubled. During the fastest growing period—August and September—the mean daily temperature is about 83°F. At the end of October the mean has fallen to about 74°F which difference accounts for the delay in the Autumn flush.

Pot culture experiments carried out at Tocklai during the past two years have yielded interesting results. The relationship between temperature, humidity and rate of transpiration has been observed and correlated with the observations of other workers made on different plants. It has also been noticed that the rate of transpiration is an index of the health of the plant. When transpiration decreases, wilting or blight attack, not evident at the time, follows in a few days.

Observations show that the ideal tea weather is, maximum temperature about 92°F, minimum temperature, accompanied by saturation, about 82°F. These values naturally vary with other factors like wind and radiation.

It seems probable that humidity affects the *amount* of growth rather than the *rate* of growth which depends more on the temperature. Thus a high humidity might force two shoots instead of one but a high temperature would bring about rapid growth of these shoots.

The wind and the radiation factors have not been studied in any detail. Ordinarily the wind, if hot, is moist. In February 1919, however, a hot dry wind blew for some days with the result that the leaves wilted and many bushes were left almost bare. Under normal conditions these factors are seen from the correlations above to be insignificant compared with temperature and humidity.

Reverting now to the question of autumn quality in teas it is interesting to consider how this is affected by climate. It is generally understood that the slower rate of growth of the late flushes has a great effect on quality. Reed (7) studying the cell sap of young fruit trees discovered that the concentration

decreased as the rate of growth increased and also that it increased as the season advanced. He also discovered that the concentration of cell sap with heavily pruned trees is less than that of others. This is due to the quicker growth which comes with heavy pruning. The cell sap is most concentrated in the tip of the leaf. All these observations may well apply to tea and it seems highly probable that cell sap has a great deal to do with tea quality.

It has been noticed that the addition of water to the soil reduces the concentration of the cell sap. If cell sap concentration is connected with quality, then the moist condition of the soil in July and August will have much to do with the poor quality teas of these months.

In accordance with generally accepted ideas it has been shown (5) that the amount of dry matter in the leaf throughout the season varies inversely as the amount of leaf grown.

Another factor, and one of great importance, is the effect of atmospheric conditions on manufacture. It was pointed out on page 15 that during the latter part of the season the vapour pressure of the atmosphere falls at a greater rate than the temperature. Thus all through the monsoon the atmosphere is nightly saturated. This state of affairs first became definite in 1921 on June 20th. From September 16th to November 16th, the atmosphere was not saturated at night although after the latter date it was so. During this dry period a good wither is possible.

On page 14 are given two sets of factors correlating the transpiration of leaves and the evaporation of water with climatic conditions. During the earlier part of the withering process of the tea leaf drying takes place according to the former set of factors for the leaf is still alive and is wilting. As the leaf gets drier the vital actions going on in the leaf cells give place to physical actions and the drying then follows the second set of factors. The leaf is now truly withering. During the wet season, leaves at the end of an 18-hour wither still contain about 70% moisture—a decrease of 5% on the moisture in the fresh leaf—whereas during the autumn the moisture falls to 60%. This difference denotes a profound alteration in the vitality of the leaf and is probably

followed by equally important differences in the chemical actions going on in the leaf.

Autumn quality is the product of the factory no less than the product of the bush.

The Soil Condition.

The soil condition includes moisture content, aeration, tilth, temperature and many other more complicated factors. The main question is soil moisture and here is one of the chief problems of the tea planter. It is a difficult problem to drain sufficiently to carry away 100-- 200 inches of rain precipitated during six months and to conserve the few inches which fall during the remainder of the year.

The late autumn rain can be fairly well conserved by the mulch left after the end of the season's deep hoe. A mulch, however, acts in two ways and may prevent the small quantity of rain falling at Christmas time from entering the soil.

The greater trouble is an overmoist soil. The maximum and cumulative effect of this factor is seen in August when a great crop depression is noticed. Such instances were observed in 1920 and 1921.

During the year under consideration the moisture was estimated daily on the Tocklai Clearance. The soil is a silty sand with an optimum water content of about 14%. Early in April the moisture content rose to 18% and till the middle of November it kept above 18% except on one or two occasions. Thus in the middle of May and towards the end of July the soil dried to some extent. These instances naturally fit in with a falling off in rainfall.

During the rains a certain amount of hoeing must be carried out and from such work increased crop results, but the tilth of the soil is often damaged. In some cases where hoeing is done during the rains the clods appear like bricks and for all practical purposes are no longer a part of the soil as a medium for supplying plant food. In such cases the increase in crop is due to the removal of jungle and partial aeration. In the Surma Valley it

happens in some cases that the spread of the bushes shuts out the light from the soil, and jungle cannot grow. Even in these cases, forking results in an increase of crop. Here the increase is due wholly to aeration.

The effect of very heavy rain is interesting. Thus 7 inches during the rains have no more effect on the soil moisture than one inch or so. Although the water holding capacity of Tocklai soil is about 40%, the moisture content seldom gets above 21%.

The Tea Crop in 1921.

On the curve is shown the tea crop, in lbs. green leaf, for the Tocklai Clearance--an area of $3\frac{1}{2}$ acres. The tea on this area was put out in 1914 and consists of half acre blocks of Burma, Kalline, China, Kharikatia, Singlo, Panighat and Betjan bushes.

The 1921 season was normal, so far as the tea crop was concerned, until the end of October. The failure of the rainfall in November accounted for the short crop. The season on the whole was a very wet one and this made for good wood.

There are, as has been mentioned elsewhere, usually six flushes in a season, but these naturally cannot be correlated with any particular variation in the weather. The flush may be hastened or delayed by a few days and the size of the flush may vary. The maximum effect of any weather peculiarity is evident about three weeks after such weather.

The May flush in 1921 was fairly late (about 10 days later than in previous years) owing to the abnormally wet April. It was however a big flush and spread over two weeks and was greatly helped on by the hot fortnight ending May 8th.

The June flush was similarly late not only following on the previous flush but owing to the cool three weeks ending June 5th.

The July flush followed quickly on the June flush although during the actual time of plucking there was a considerable fall in temperature. The depression which followed has often been observed.

A phenomenon which is likely to occur, especially about midway through the season, is *banjhi*-ness when the shoot becomes dormant. The exact significance of this state is not yet understood, for although a bud may be *banjhi*, the first and second leaves may be growing with great vigour. It was at one time thought that the *banjhi* state denoted complete equilibrium between the amount of food taken in by the roots and the amount necessary for the bush to function. The fact that a change in the weather, such as a break in the rain or the end of a drought, or the disturbance of soil conditions by cultivation ends a period of *banjhi*-ness, supports this idea. But the fact that individual branches become *banjhi* and that *banjhi*-ness is confined to the growing point of a shoot suggests that the cause is more complicated.

The August flush extended over two weeks. By the end of September the total rainfall was well above the average, which pointed to an early close to the season. The Autumn flush extended over 3 weeks. Its heaviness was due partly to big leaf which resulted from the delay of a few days between the August and September flushes and partly due to the round of hoeing put in during a dry spell towards the end of July. Previous to this, the jungle had become very thick.

Early in October the wind turned to the North, the rain tailed off and the temperature and humidity fell so sharply that all chances of a November flush vanished.

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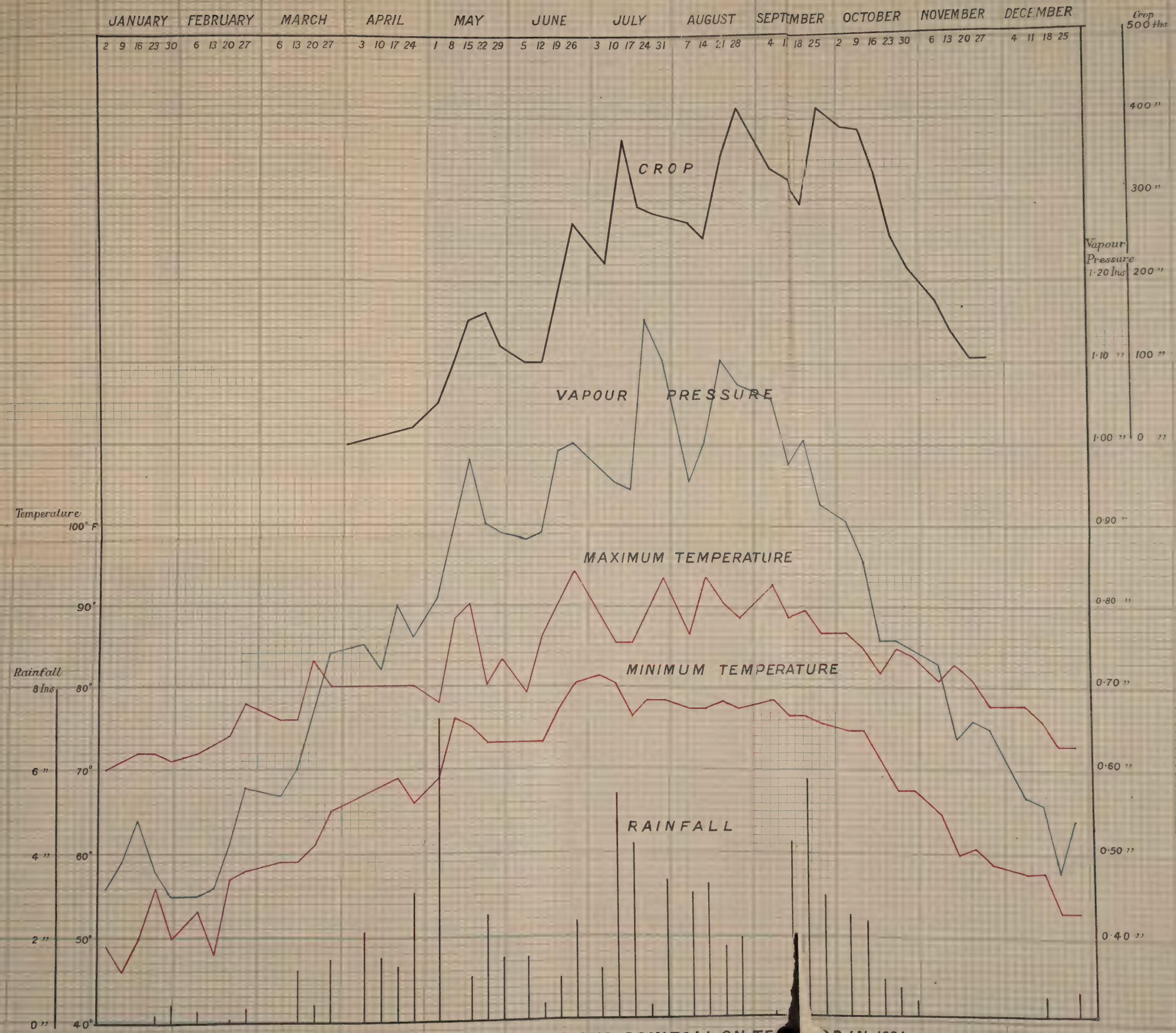
SEASON 1921



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EXPERIMENTS ON THE MANURING OF GREEN CROPS. *

(Season 1921)

BY

H. H. Wiles, M.A.

This series of experiments has now been in progress for four consecutive years, and the results obtained during 1921, while they amplify and to a large extent confirm those obtained in previous years, are also of quite exceptional interest in themselves by reason of the enormous percentage increase shown by all the manured plots over the check plots.

In last year's article on this subject Cooper (1) remarks :— " The residual effects are very great and it is clear that a single application of certain manures has effected an increase in fertility which will extend over many years."

This year's results have confirmed both the statement and the prophesy, and though it would not perhaps be true, in view of the somewhat smaller crops obtained on most of the plots during 1921, to say that the residual effects are greater than they were last year, it can be definitely stated that all the manures applied have produced a very marked increase in fertility, which, in several cases, show signs rather of increasing than decreasing in this the fourth year after application.

The following table gives crop records of the various plots during the past four years :

* For previous articles see *Quarterly Journal*, 1918, Part IV (page 106) and 1920, Part II (page 48).

MANURING	lbs. per acre.	Plots.	Crop in tons per acre. 1918	1919	1920	1921
Check		3	2·83	·82	·97	·16
Slaked lime	800	2	2·43	1·14	1·99	1·73
Crushed limestone	1200	1				
Slaked lime	800	2	3·09	1·49	2·04	2·32
Sulphate of Ammonia	150					
Crushed limestone	1200	1				
Sulphate of Ammonia	150					
Carbonate Magnesia	900	2	3·34	1·39	1·89	1·15
Sulphate of Ammonia	150					
Salked lime	800	2	3·26	1·62	2·31	2·14
Sulphate of Ammonia	150					
Sulphate of Potash	75					
Crushed limestone	1200	1				
Sulphate of Ammonia	150					
Sulphate of Potash	75					
Slaked lime	800	2	0·49	1·83	3·55	3·31
Sulphate of Ammonia	150					
SULPHATE OF POTASH	8200					
Crushed limestone	1200	1				
Sulphate of Ammonia	150					
SULPHATE OF POTASH	8200					
Slaked lime	800	2	2·70	1·28	2·03	1·89
Nitrate of Potash	50					
Slaked lime	800	1	2·64	2·53	3 10	3·04
NITRATE OF POTASH	2500					
Slaked lime	800	2	4·23	1·48	2·44	1·68
Sulphate of Ammonia	150					
Superphosphate	150					
Crushed limestone	1200	1				
Sulphate of Ammonia	150					
Superphosphate	150					
Slaked lime	800	2	4·05	2·70	3·56	2·85
Sulphate of Ammonia	150					
SUPERPHOSPHATE	8200					
Crushed limestone	1200	1				
Sulphate of Ammonia	150					
SUPERPHOSPHATE	8200					

NOTE :—The area of each plot is approximately 1/50th of an acre.

It will at once be noticed from the above table that this year's crop shows a decrease from last year, although only a comparatively small one ; the average being 2·03 tons per acre as against 2·39 in 1920.

While this decrease is only what one might naturally expect, owing to the gradual lessening of the effect of the manures together with the loss of a certain amount of fertility by the soil, due to the complete removal of the crops annually for three years, it is probably actually due in a far greater measure to the unfavourable weather conditions prevailing at the most critical period in the growth of the crop.

The crop (Vigna Catiang) was sown on April 18th, excellent brown imported seed being used, and it was originally intended to grow it for six weeks only, as in previous years. The seed germinated quickly and the young seedlings at first came up well, the weather during the first fortnight after sowing being very favourable. During almost the whole of May, however, which should normally have been the principal period of growth, conditions were bad owing to excessive bright sunlight, dry winds and no rain, and growth was almost entirely checked. Indeed the majority of the plants were so backward at the end of six weeks that it was decided to leave them in the ground for another month. However, favourable conditions set in during the last few days of May, and continued throughout June with the result that the plants began to flower on the phosphate plots after nine weeks in the ground, and the crops from all plots were accordingly pulled up and weighed on June 22nd.

Another point to be taken into consideration in comparing the figures for 1921 on the above table with those for previous years, is that whereas the latter represent actual yields, this year's figures have had to be calculated, owing to the planting, in January 1921 of two lines of tea in each plot, which necessitated a different method of sowing the green crop.

The reason for planting these plots with tea is to ascertain whether the manures applied will produce an effect on the tea

similar to, or different from, that produced on green crops ; and, if the former, to what extent the results are directly comparable.

The cowpeas in this instance were sown in three strips per plot, between and on each side of the tea, each strip being composed of four rows with seeds 3″ apart in the rows. The actual number of seeds sown per plot was therefore known, and a correcting factor has been applied in order to convert the actual crop results obtained to one which can be directly compared with the broadcast sowings of previous years.

Comparing the 1921 crops with 1920, the greatest decrease, apart from the check plots has occurred on the plots receiving Superphosphate, of which both large and small dressings show a loss of about ¾ of a ton per acre, the figures being approximately the same in each case as in 1919, which was also a bad crop year. This loss is probably partly due to the fact that these plots alone were past maturity when gathered.

As noted by Cooper (2) last year, the crops on these plots come early to maturity and those on the plots which received the heavy dressings were the only ones fit to be gathered at the end of six weeks. By the time they were pulled up, they were in full bloom, while a few plants here and there had even seeded, and there was considerable yellowing and leaf-fall apparent.

Disregarding for the moment the Superphosphate plots, the check plots again show by far the heaviest loss (0·81 ton per acre) followed by the plots receiving Magnesium Carbonate, the yield from which has decreased by 0·74 tons per acre.

So far as the check plots are concerned, these figures support the theory that where no manures have been applied rapid soil-deterioration has already taken place, as a result of continued cultivation and removal of the crops grown.

The marked superiority of the plots which have received lime over those which have not, is well shown in the curves at the end of the articles and by the grouping of the plots in Table No. II, and, so far as can be judged from the results obtained during the past four years, it can safely be stated that *lime has a*

decided value in the preservation of fertility in acid soils under continuous green-cropping.

Within what we may term the 'Lime' group the decrease in yields falls into four quite distinct sub-groups. The first comprises (not unnaturally) the plots to which lime only was applied, and also the large Sulphate of potash plots, with decreases of 0·26 and 0·24 respectively. This is followed by the small Sulphate of potash group with a loss of 0·17. Both small and large applications of Nitrate of potash come next with only 0·14 and 0·06 decrease respectively while the remaining group, namely, that receiving lime and Sulphate of ammonia only, is the only one which does not show any loss for 1921, the yield being 0·28 tons per acre above that for 1920.

If these small differences may be regarded as having any definite meaning, they would appear to indicate that the beneficial effect of the potash manures, and particularly of the Nitrate of potash is still very considerable, while the action of the purely nitrogenous manure (ammonium sulphate) is still so strong as to counteract the loss of nitrogen from the soil, caused by continual pulling up of the crops, by over a quarter of a ton per acre.

We now come to the consideration of Table II, which, as in previous articles on this subject, shows the increase per cent. of the manured plots over the checks.

The order of the plots has been somewhat altered however in order that all those receiving manures of the same or a similar nature might be arranged together in groups and sub-groups.

Group.		Manuring.	Percentage increase over check plots.			
			1918	1919	1920	1921
NO LIME		Carbonate of Magnesia ... ... Sulphate of Ammonia	18	71	95	726
(A)		Lime only	—14	44	105	1100
(B)		Lime ... ... Sulphate of Ammonia	9	62	110	1466
(C) SUPERPHOSPHATE. Av. Inc. % 1429·5 Inc. over other plots 15·5%		(*a*) Lime ... ... Sulphate of Ammonia ... ... Superphosphate	49	81	153	1053
		(*b*) Lime ... ... Sulphate of Ammonia ... ... SUPERPHOSPHATE	41	224	267	1804
(D) POTASH. Av. Inc. % 1651 Inc. over other plots 421%	SULP. OF POTASH. Av. Inc. % 1729 Inc. over other plots 401%	(*a*) Lime ... ... Sulphate of Ammonia ... ... Sulphate of Potash	14	100	140	1353
		(*b*) Lime ... ... Sulphate of Ammonia ... ... SULPHATE OF POTASH ...	—83	121	266	2105
	NIT. OF POTASH. Av. Inc. % 1573·5 Inc. over other plots 215·5%	(*c*) Lime ... ... Nitrate of Potash	—5	57	109	1230
		(*d*) Lime ... ... NITRATE OF POTASH ...	—7	210	219	1917

(Average Inc. % 1503·5. Inc. over other plots 777·5%.)

LIME.

In order to facilitate the reading of the individual "plot" curves as percentage values of the original unmanured soil, an additional scale is given on the right hand side of the chart on which the value 100 has been given to the yield from the check plots in 1918, the year of first application of the manures.

The most noticeable feature of both the Table and the Charts is the sudden very great rise in percentage increases this year throughout the series.

This is partly, but by no means entirely, accounted for by the fact that very poor crops were obtained on two of the three check plots, these having suffered disproportionately from the adverse weather conditions in May, owing to the decreased fertility of their soil. All the other plots, however, suffered to some extent, though probably in a lesser degree, from the same cause.

A further explanation must therefore be looked for as to why the 1921 crops from the majority of the plots show little or no decrease in spite of the poor season, and it is in the increased and possibly still increasing fertility of the manured plots, rather than in the decreased and decreasing fertility of the check plots, that it is probably to be found.

In this connection it will be especially noticed that the Magnesia and Superphosphate plots are the only ones which show a marked decrease from 1920—a favourable year for green crops. Further, the former are the only plots which do not show a decided increase over the yield for 1919, which was the only previous unfavourable season, and even this may be accounted for by the inclusion in the results for 1921 of the third "Magnesia" plot, which has been disregarded in working out the figures for previous years as being abnormal, owing to the presence on it of a large white-ant teelah, which had to be dug out when the experiment was started, thereby causing the removal of almost all the surface soil from this plot.

Apart from marked increases over the check plots shown by all manured plots in common, it is of interest to note that the potash salts have this year given decidedly larger increases in crop

than Phosphoric acid (as Superphosphate), Sulphate of potash being easily first, the Nitrate second, and Superphosphate third, both for the small and large applications.

Leaving the excessive doses of potash and Phosphoric acid out of consideration however, we again find Sulphate of ammonia at the head of list and Magnesium carbonate at the bottom of it as on Table No. I ; " Lime only " holding fourth place just above the small dose of Superphosphate.

These positions are largely what one would have expected to find, and in this connection a brief consideration of the action of the various manures applied will not be out of place.

The action of most chemical manures on an acid soil, such as the one with which we are dealing, is two-fold.

Such manures are, of course, usually applied mainly, if not entirely, for their food-value to the crop which it is desired to produce, but their action is by no means entirely, or even primarily, biological. On the contrary, the immediate result of applying most manures of this kind to an acid soil is a purely chemical one.

One of the most important results of this, and of the previous series of similar experiments at Borbhetta by Hope and Andrews (3), has been the very marked way in which the initial depressing effect of potash, as contrasted with the immediate stimulating effect of Phosphoric acid (as Superphosphate) has been brought out, both in the case of tea and of green crops.

Chemical analysis of the Borbhetta soil—which is typical of the acid Tea soils of this part of Assam—reveals the presence of certain salts of aluminium, which are either soluble in water themselves, or at least potentially capable of producing Alumina in soluble form, if acted on by the salts of strong acids, such as some of the chemicals with which we are dealing.

Carpenter and Harler (4) have shown that such " soluble Alumina is toxic," even when present only in such minute quantities as one part per million, and the same writers attribute the initial depressant effect of potash manures on tea and other crops directly to the power of this chemical of converting insoluble salts of

Aluminium into a soluble form, in which they immediately pass into the soil solution and exercise a toxic effect on the crop.

Superphosphate on the contrary, the action of which has been very thoroughly worked out by Meggit (5), has exactly the opposite effect on these soils, as also has Lime.

For, whereas potash manures tend to liberate soluble Alumina, lime or phosphatic manures tend to fix any that may already be present in the soil solution as insoluble Aluminium phosphates or oxide, or as Calcium aluminate, none of which salts have any toxic action on plants.

These facts are clearly borne out by the figures on our tables, which can thus be the more readily understood.

The initial depressant effect of the potash manures, so noticeable at first, has now worn off completely, normal soil conditions having become re-established as the percentage of potash in solution has gradually decreased until it has become too weak to liberate further toxins, with the result that the very considerable food value of these manures has been able to exert a steadily increasing beneficial effect on the crop, as compared with that of the check plots, during the last three years.

Phosphoric acid (as Superphosphate), on the other hand, was immediately available as plant food from the start, being subject to no such check from toxic alumina as that suffered by the potash plots, but rather the reverse, with the result that its food value is now declining, partly owing to exhaustion, but also possibly partly to the gradual reversion to the soluble (toxic) form of the Alumina which it rendered insoluble when first applied.

Summary.

Apart from a slight general decrease in crops due to the seasonal influence, this year's results may be compared with those obtained in the three previous years as follows :—

(1) *Lime alone* continues to produce a definite increase in fertility and has more than maintained its superiority with regard to the check plots.

(2) *Magnesia* (with Ammonium sulphate) on the contrary has fallen away considerably, both as compared with the combination of Lime and Ammonium sulphate or with Lime alone, though it has practically maintained its position with regard to the check.

(3) *The Potash Manures* in every case continue to show very big increases over the check plots, when considered in conjunction with Lime and Ammonium sulphate. In the case of the plots receiving Potassium sulphate, however, this is probably largely due to the additive effect of all three manures, for, if the beneficial effects of the Lime and Ammonium sulphate are eliminated from the calculation, it will be seen that the decrease in yield on these plots is only slightly less than that on the checks.

On the other hand the relatively very small decreases in actual crop shown by the Nitrate of potash are probably due entirely to seasonal influence, but for which there would apparently have been a decided increase in yield from these plots this year.

(4) *Phosphoric Acid* (as Superphosphate) has barely maintained its position in relation to the check-plots, even with the assistance of Lime and Ammonium sulphate. The crops on these plots, however, had suffered dis-proportionately from prematurity when gathered, although this cannot entirely account for the decreases shown by them.

Conclusions.

(1) Ten maunds of Lime still produces in the fourth year after application a strong residual effect.

It apparently tends at least to maintain if not to raise the fertility of all plots to which it was applied either alone or in conjunction with other manures.

(2) Magnesia now shows a rapidly diminishing effect, and

after the second year its value has always been definitely inferior to that of lime.

(3) Phosphoric Acid shows no further increase in fertility in the fourth year either for the large or small dressings of Superphosphate, but rather the reverse. The residual effect, however, is still sufficiently strong to maintain very large crop increases over the check-plots, and, in the case of the heavy dressing only, an increase of half a ton per acre over the 3 plots receiving no Superphosphate but the same other manures.

(4) Potash salts continue to show marked beneficial effect after a lapse of four years, this being especially so in the case of the Nitrate, which has this year produced greater increases in fertility than any other single manure with the exception of Ammonium sulphate.

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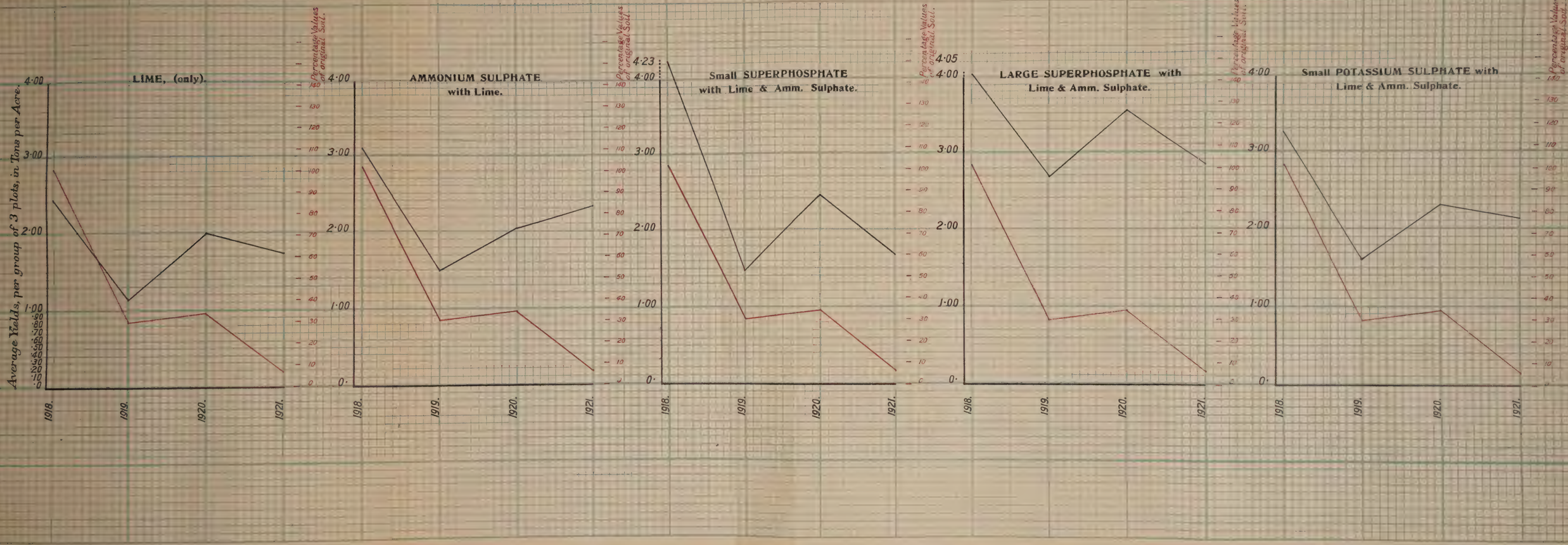
RED LINES DENOTE YIELD FROM CHECK PLOTS.



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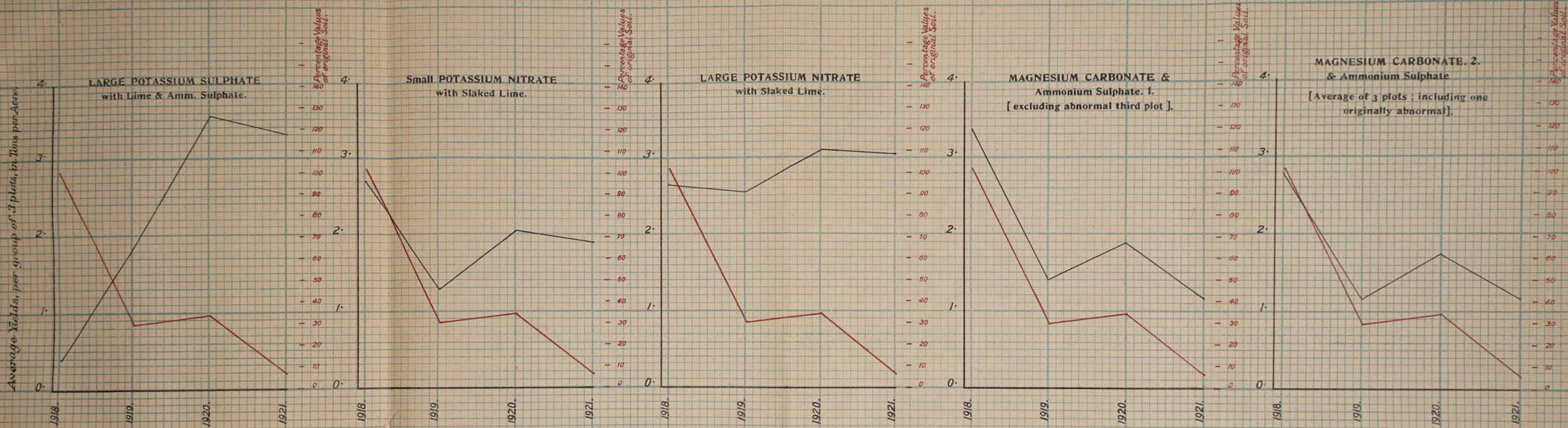

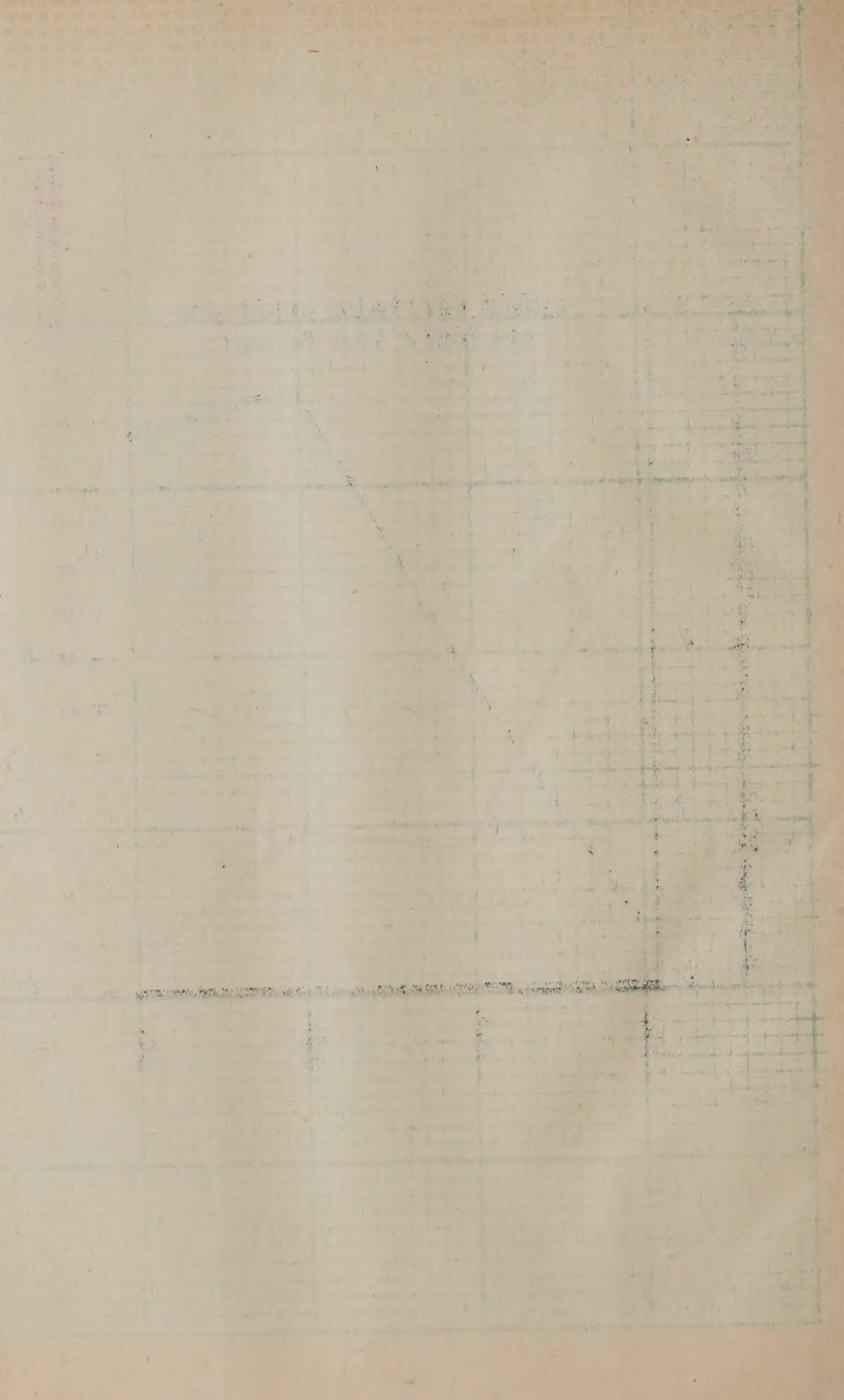

NOTES.

The Preservation of Timber—The chief and effective preservation of timber from attack by fungi and insects is a problem which is constantly before the planter. Many processes have been recommended, most of which demand that the timber should be either kiln-dried or treated with preservatives in a vacuum. Neither of these two processes is possible on a tea garden. The recommendations put forward by the Forest Products Laboratory, U. S. A., which follow, may therefore be of some interest. Green timber which cannot be kiln-dried is liable to attack by fungi, many of which produce blue stains, and which in any case render the timber liable to rot. It has been found that the attacks of fungi may be prevented by dipping the wood into warm solutions of either sodium carbonate (soda ash) or sodium bicarbonate. In wet weather an 8 per cent solution of the carbonate, or an 11 per cent solution of the bicarbonate, can be used, and the concentration of the solution can be reduced to 4 and 5 per cent respectively in dry weather. The timber should be treated immediately after sawing and then piled in such a way as to ensure ample ventilation.

This recommendation seems delightfully simple, and would be inexpensive, and with the authority of the Forest Products Laboratory behind it would seem to be well worth a trial, more especially since soda ash is easily procurable and is now-a-days kept in stock on most up-to-date gardens.

E. A. A.

Temperature control of firing machines.—At the present time when the necessity for the production of the best tea possible is of paramount importance, all that can aid in this direction is of importance and any mechanical device that will help to the attainment of greater control of the operations in tea manufacture needs to receive careful attention, and perhaps one of the processes that

is difficult to continually control throughout the working period is the temperature of the firing machinery. The fluctuations in the temperature can be rapid and of considerable amount through uneven firing, and unless a constant watch can be kept upon the machine thermometer there is no means of ascertaining whether this operation has been properly carried out. The thermometer on many machines is in such a position that it is difficult to read. An instrument that affords a means of simply and efficiently controlling the firing operation is a recording thermometer, of which there are several different makes at the present time on the market. A type, however, that has given good results in this direction is one of the type made by the Brown Instrument Company, Philadelphia, and is now quoted at the price of 60 dollars.

Whilst such an instrument is of use in any tea factory it is more particularly so in those factories where an Assistant Manager cannot constantly be in the factory during the time of manufacture. The instrument gives a continuous record of the temperature of the firing machine during the period it is at work and any irregularity in firing can be ascertained as also the extent of the irregularity and the time at which such occurred. The more extended use of recording thermometers in tea firing machinery is to be advocated as a means of assisting towards more efficient working.

P. H. C.